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THE MOUNT WILSON SOLAR OBSERVATORY

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The Mount Wilson Solar Observatory, one of the eleven departments of research of the Carnegie Institution of Washington, was established in 1904. Its astronomical instruments are on Mount Wilson in Southern California, 5700 feet above sea level. In the valley, in the neighboring city of Pasadena, are the library, the physical laboratory, the machine and optical shops, and the administrative offices of the Observatory.

Members of the scientific staff remain on the mountain only while engaged in the work of observing. All reductions and calculations are made at the office in Pasadena, where the services of the Computing Division are available. The staff includes a scientific personnel of about thirty individuals and an equal number of opticians, draughtsmen, instrument makers, machinists, and other assistants.

Since its inception, the Observatory has been under the direction of George Ellery Hale, and the features which make it unique are an expression of his originality, and his boldness and freedom from tradition in attacking new and difficult problems. The Observatory is more than a fulfillment of the plans for its development, for the plans themselves were the outcome of long years of experience at the Kenwood and Yerkes Observatories, where the investigations undertaken by Dr. Hale were preliminary to those now in progress at Mount Wilson.

Observatories are sometimes planned before a definite program of astronomical observation has been formulated. The instrumental equipment then provided is commonly of a certain conventional type, applicable with nearly equal facility to various recognized lines of investigation. Some freedom of choice and a pleasing richness of opportunity are thus open; but the very diversity of the things that may be undertaken sets a limit to what can be accomplished. The conventional pattern of the tools sometimes makes them useless for the job that is special or peculiar.

But with the Solar Observatory the problem has always preceded design and construction. The Observatory was brought into existence for a perfectly definite purpose, and its original expeditionary character was changed to that of a permanent institution of research because definite questions required continued study with highly specialized instruments. Its initial purpose and all its early equipment were concerned with the Sun, but other fields of activity have been in view from the first, and could not well have been ignored.

The many questions raised by the varied phenomena of the Sun are not limited to the solar system. They suggest an equal number of questions as to the phenomena of other suns, and we are instantly at face with the great problem—the history of the universe of stars; for the stars are also suns, not so different, in the average, from our own.

The stars must accordingly be studied both for their individual peculiarities and for their relations to each other and the things which are common to all. What we observe in the Sun can find its full explanation only when examined from the wider viewpoint of the universe of suns, just as human personalities are to be comprehended only when the influence of race and civilization, and all the varied and intricate forces of environment are measured and brought to a resultant. The ultimate problem—the growth of the stellar system, its past history and probable future development—thus appears with a clearness of statement little justified if one thinks only of an immediate solution. But however remote a satisfying solution, and however insurmountable the intervening obstacles, the goal must be marked, if the things that may be done now are to be brought into proper correlation and utilized to their fullest efficiency.

We may say, therefore, that the purpose of the Solar Observatory is the study of stellar evolution; its actual operations, however, are concerned with numerous special questions, carefully selected and co-ordinated, which have a critical bearing on the problem of stellar development. These are far more diversified than might be inferred from a too literal interpretation of the Observatory's name, and fall into two groups, one concerned with the distribution, distances, motions, spectra, colors, and brightness of the stars, and all specialized questions relating to their physical condition, the other with those phenomena usually associated only with the

Sun, but here recognized as stellar characteristics revealed in the one star within reach of detailed observation.

Since we must observe faint stars as well as the brightest object of the heavens, different types of instruments are required. For the stars, telescopes of great light gathering power are necessary; when their spectra are to be examined, moderate or low dispersion alone can be employed, for the luminosity gathered even by a great telescope is insufficient unless the spectrum be small. With the Sun there is an abundance of light; high magnification and great dispersion can accordingly be used.

As most observations are made photographically, the telescope of a modern observatory is only a camera adapted to the needs of the astronomer. The principles of design are those which guide the photographer himself in selecting his instrument: for pictures of large scale, the objective is of long focus; thus the telephoto attachment is a device for increasing focal length without exceeding the convenient dimensions of the ordinary camera; for difficult conditions of illumination the objective is of large relative aperture, in order that the exposure times may fall within practical limits. Focal length therefore means magnifying power, while large aperture is the critical factor in dealing with faint objects. For stars the linear diameter of the objective is important; but for objects of perceptible dimensions, it is only the ratio of aperture to focus which counts.

For solar observations we thus select telescopes of moderate aperture, but, since the magnification is to be extreme, of a focal length as great as various limiting conditions will permit. For stars we need an objective or mirror of the greatest possible size, combined with a focal length appropriate to the problems to be solved. These details are elementary, but they show why the instruments of the Solar Observatory have the form they possess.

For important advances, it was evident that telescopes of unusual dimensions would be required, a circumstance emphasized by the desirability of using, with telescopes of long focus, spectroscopes also of great focal length, in order that the spectra of the Sun and the stars might be studied under a dispersion greater than any previously employed. Engineering difficulties were thus raised whose solution has led to unusual types of construction and mounting.

The first of these instruments, a solar instrument and the sim-

plest in design, was the Snow telescope, originally constructed for the Yerkes Observatory but later acquired for use at Mount Wilson. Its principle is that of the photoheliograph so successfully used for the observation of eclipses. A coelostat, consisting of two movable flat mirrors, reflects a beam of light into a concave mirror of 60 feet focus which returns the rays in a horizontal direction to the focal point and forms an image of the Sun 6.7 inches in diameter. The more important pieces of auxiliary apparatus are a spectrograph of 18 feet focus and a 5-foot spectroheliograph.

Experience with this instrument indicated that important advantages would be secured by placing the optical axis of the telescope in a vertical position—with the Snow telescope it is horizontal. The beam of light would then cut the atmospheric strata perpendicularly, its mean elevation above heated layers close to the ground would be greater, and the spectrograph could be placed in a subterranean pit under practically constant conditions of temperature.

The first of the tower telescopes was accordingly constructed, its focal length, like the Snow telescope, being 60 feet. The beam of sunlight is thrown vertically downward thru a 12-inch objective by a coelostat at the top of the tower, the solar image being formed 60 feet below in the observing room at the base. The light passes thru the slit downward into the pit containing the body of the spectrograph; it is dispersed into a spectrum band and returned to the surface where it is registered on a photographic plate, thus revealing the spectral peculiarities of that part of the solar image lying on the slit, whether the photosphere, the chromosphere, or a sun-spot. The pit also contains a spectroheliograph used for a study of the distribution of various incandescent gases in the solar atmosphere.

The 60-foot tower telescope is of a type not previously tested, and accordingly was moderate in dimensions and simply constructed. But trial demonstrated the usefulness of the principle and showed that even greater focal length, with correspondingly greater magnification, might be employed. Plans were then made for a second tower telescope, with a focus of 150 feet, capable of producing a solar image 17 inches in diameter. With this instrument minute details of the solar surface, not hitherto observed, can be studied with ease. A spectrograph of 75 feet focus,

mounted in a deep pit beneath the tower, has a dispersion 2½ times that available with the 60-foot tower; the scale is such that the visible region in the third order spectrum has a length of about fifty feet. These instruments, the Snow telescope and the two tower telescopes, are the main equipment for solar observations. Altho each has proved more efficient than its predecessor, none has been superseded, and the 60-foot tower, which is especially useful, has recently been given a more permanent mounting than it formerly possessed.

The power of these instruments is indicated by what has been accomplished by their use. Thus an extended investigation of the solar rotation has been made; new values of the angular velocity and the equatorial acceleration have been found, and it has been established that the velocity of rotation is to some extent a function of elevation in the solar atmosphere, the vapors of calcium and hydrogen moving faster than the low-lying, heavier vapors. The chromospheric spectrum has been examined and mapped with a precision and detail not hitherto possible. Important differences between the center and limb of the Sun have been observed; the general circulation of various vapors of the solar atmosphere has been studied, and also the more complicated vortex movements in the vicinity of sun-spots. The close similarity of sun-spot spectra and the spectra of red stars like *Arcturus* has been established, and it has been demonstrated that within the spot umbra the temperature is lower than in the adjoining photospheric regions.

It has been found that every sun-spot is the center of a powerful magnetic field, and in numerous instances the strength of the field has been measured and its variation with elevation and with distance from the center of the spot has been studied. The polarities of spot-groups have been investigated, whence it appears that the members of the double or bipolar groups are almost invariably opposite in polarity; the distribution of polarities within the groups and in each hemisphere is expressed by a simple law; but a reversal of the whole system of polarities is in some way associated with the transition from one cycle of sun-spot activity to that immediately following.

From observations of the magnetism of spots it was but a step to observations of the Sun as a whole, to determine whether it has a general magnetic field analogous to that of the Earth. A

laborious investigation has given an affirmative answer: as a first approximation, the Sun acts as a uniformly magnetized sphere, with its magnetic axis inclined some 6° to the axis of rotation. Other illustrations might be given, but the enumeration is not intended to be complete, and we turn to a feature of the Observatory's organization without which some of the things mentioned could not have been accomplished.

The astronomer is at a disadvantage as compared with the chemist or physicist. He is powerless to vary the conditions which determine the character of what he observes; he cannot cause the repetition of any single phenomenon for a more leisurely study of its details, nor does he know what would have occurred had the conditions been differently ordered. Often he can only wait for time, to shift changing configurations slowly into view, as the varying positions of the planets. Sometimes, in the slow transformations of an evolutionary process, he can bridge endless intervals of time and picture the changing details by studying, among the individuals affected, those which simultaneously find themselves in different stages of development. But frequently, without further clew, he can make no progress at all. The phenomena are so complex and their causes so obscure, that he is at a loss as to how to proceed. Especially is this true of occurrences in the atmosphere of the Sun or a star, where he finds in operation powerful and little understood hydrodynamical forces, the intricate and confusing effects of fluctuating pressure and temperature, the complicating influences of powerful magnetic fields, and perhaps also those of extreme electrostatic conditions. From this maze there seems but one means of escape: to enter the physical laboratory and, by empirical methods, discover conditions which reproduce the phenomena viewed at the telescope. Astronomy to some extent can thus be made an experimental science, and the astrophysicist becomes a physicist whose laboratory includes the heavens as well as the earth.

Simple illustrations make clearer the principle involved. Simplest of all is the identification of terrestrial elements in the spectra of the Sun and the stars. This of course could not have been done at all without parallel investigation in the laboratory; but the result is so familiar, and usually receives such emphasis as an astronomical achievement, that we forget the indispensable link in the evidence supplied by the physicist.

A more recent accomplishment, possible only with highly specialized laboratory equipment, relates to the temperature of sun-spots. Enormous numbers of faint, closely packed lines, not to be identified with any known element, appear in the spectrum of a spot. Laboratory investigation proves them to be associated with chemical compounds which exist only at temperatures known to be lower than that of the photosphere surrounding the spot. The inference as to the temperature of the spot is obvious. Again, many lines in the spectra of sun-spots are widened, or even split into separate components. An analogous laboratory phenomenon —the Zeeman effect,—is well known. It appears when a magnetic field surrounds the luminous source of a spectrum, and the solar phenomenon may be a Zeeman effect originating in a magnetic field surrounding the spot; but this is only an inference. Comparing, however, line by line, the spectrum of the spot with those of the laboratory, we find in the different lines a parallelism of structure so exact as to leave little question as to the phenomenon with which we are dealing; and when the resources of the laboratory are further applied, we find in corresponding components of solar and laboratory lines an exact similarity in the polarization phenomena which are a unique characteristic of the Zeeman effect, and the matter is put beyond doubt. With laboratory aid we may go even farther, for the quantitative relations which can there be established, under conditions within control, give at once the strength of the field surrounding the spot.

These illustrations suggest the constant demand for precise and detailed laboratory data. To meet this the equipment must be extensive and powerful, and capable of results comparing in precision with the astronomical data they supplement. The laboratory of the Solar Observatory has accordingly been provided with electric furnaces, powerful electro-magnets, and spectrographs of the most modern and efficient type; one of 30-feet focus, mounted vertically in a well, is essentially a duplicate of that beneath the 60-foot tower on Mount Wilson. The laboratory has also much other apparatus and ample sources of electric power, including high tension currents, both direct and alternating.

For the problem of stellar evolution there must be varied and numerous observations of the stars themselves. Their distribution and brightness, their motions, spectra, and colors must all be determined with precision for a large number of objects in all parts

of the sky, and of all magnitudes from the brightest to the faintest. Not merely individual stars, but star clusters and nebulae must also be observed. An instrument of the highest optical power is therefore required. That in use at Mount Wilson is a reflector of 5-feet aperture and 25-feet focus. A second instrument, also a reflector, with an aperture of 100 inches is now under construction and will shortly be completed.

Altho numerous engineering difficulties had to be overcome, these instruments are not unusual in mounting. They are of the heavy, rigid, machine-type of construction introduced by Warner and Swasey for the large refractor of the Lick Observatory. The great mass of the moving parts—approximately 100 tons for the larger instrument—requires special methods of control; but the perfection and flexibility of the modern electric motor meet all requirements. The domes and buildings are of metal, with thin double walls enclosing air spaces for insulation. As there are no large concentrated masses, temperature equilibrium is quickly established at nightfall, and the harmful influence of excessive radiation during observing hours is thereby largely avoided.

The great light gathering power, essential for most stellar investigations, is afforded by the large aperture of the mirrors. To allow the range in magnification necessary for different classes of observations, the 60-inch reflector with a principal focus of 25 feet, is provided with secondary mirrors for Cassegrain combinations having equivalent foci of 80, 100, and 150 feet. Similar combinations with a maximum equivalent focus of 250 feet will also be provided for the 100-inch reflector.

The reflecting telescope has great advantages, notably its perfect achromatism—light of all colors is brought to a focus in the same plane and with equal exactness—and its freedom from the absorption effects which influence the quality of the light transmitted by most objectives; but unfortunately its field of view is very small. With the large ratio of aperture to focal length necessary for rapid photographic action, the area of good definition is only about one-half that of the disk of the Moon.

For the portrayal of extended areas, such as the cloud forms of the Milky Way, or for the registration of the spectra of large numbers of stars with the aid of an objective prism, a 10-inch Cooke triplet with a field of about 15° is available. The combination is identical with one of the modern portrait objectives, but

of larger dimensions. The relatively short focus of 45 inches gives pictures of small scale, but the penetrating power is great, and the instrument has a wide field of usefulness.

Each problem has its own requirements, and in a modern observatory the invention and design of special instruments is a feature of almost every investigation. As the construction of new forms of apparatus requires much experiment, machine, instrument, and optical shops are a necessity; and those of the Solar Observatory have always occupied an important place in its organization. All the important instruments were designed by members of the staff. Most of the optical work for the 60-inch and all of that for the 100-inch telescope has been done by the Observatory's opticians. Castings of unusual size have been machined elsewhere; but all parts requiring very careful workmanship, such as driving clocks, worm gears, slow motion attachments, etc., and all accessory apparatus, including the spectrographs, have been made in the Observatory shops. For work of unusual precision a special shop is available; among the many instruments completed here may be mentioned several comparators, one of unusual size, for the measurement of solar and stellar spectra. The most important undertaking of high precision now under way is a machine for ruling diffraction gratings of sizes larger than those now obtainable. Without such gratings the optical possibilities of the tower telescopes cannot be fully utilized.

It has long been recognized that the powers of human industry are unequal to a complete account of every object in the heavens; a telescope of even moderate dimensions reveals stars by the million. The selection of representative objects for observation is therefore a matter of much importance, and oftentimes of no little difficulty. A method of selection, satisfactory for many purposes, was suggested some years ago by Kapteyn, who proposed that the stars in about 200 regions of small area, uniformly distributed over the sky, be intensively studied, and that all possible information be accumulated with respect to their numbers, magnitudes, motions, spectra, and distances. This task would not be impossible, while comprehensive data for these Selected Areas would yield results of first importance. But even this restricted program of observation is beyond the resources of any single institution, and the responsibility for various parts of the undertaking has been assumed by different observatories.

It was not at first clear that such questions as the distribution and motions of the stars bear any relation to the problem of stellar development; but fortunately the Solar Observatory was able to undertake investigations along some of the lines in which Kapteyn is so deeply interested, and it now appears that there are relationships of an intimate kind between the details of the structure of the universe and the stage of development in which its constituent parts find themselves.

For questions relating to the physical condition of a star, the spectrograph is the most important of all instruments of research, and the program of spectrographic observations in progress at Mount Wilson has accumulated a large amount of data. In general these do not relate to objects in the Selected Areas as radial velocities were required, which restricts the choice to brighter stars. Altho systematic observations of the Selected Areas will shortly be undertaken with the 10-inch triplet and an objective prism for the determination of spectral types, the basis of selection so far has been mainly that of spectrum or proper motion. Thus the observing program has included several hundred stars of early spectral types, mainly B and A, and extensive lists of later type stars of small and large proper motions, respectively, the latter for the most part including stars of known parallaxes.

To understand the bearing of these observations, it is necessary to recall Kapteyn's discovery of the existence of two streams of stars. In general, individual stars do not move at random but display community of motion to a marked degree. Small isolated groups having a common motion, like that in *Ursa Major*, have long been recognized; but Kapteyn found that the majority of all the stars of known motion belong to one or the other of two great interpenetrating streams. The phenomenon is so obviously of fundamental importance in the history of the universe that every attempt should be made to increase our knowledge of its details. The series of observations mentioned were for this purpose, and it is of interest to see what has been learned.

The results for the early-type spectra, supplementing those previously available, show that stars of all spectral types are present in both streams, tho the proportion is not constant. As we pass from stars of solar type to those of type A, and thence to the Orion or B stars, the number of objects in one stream decreases as compared with that in the other; and, at the same time, there

seems also to be some change both in the direction and the amount of the stream velocity. This correlation of spectral type with the characteristics of stream motion illustrates the relationships existing between the stars as a system and the phenomena of stellar development, for stellar type indicates the evolutionary stage of a star, and shows the importance of examining all stellar phenomena from the standpoint of interdependence.

The second investigation, that of large and small proper motion stars, shows that the objects of small motion, the most distant stars whose radial velocities can at present be measured, also belong in general to one or the other of the two streams. Star streaming is thus no local phenomenon, confined to objects in the vicinity of the Sun, but extends to the remotest stars for which we are able to accumulate data.

A question of fundamental importance in studying the distribution of stars is that of a possible loss of light in its passage thru space. Particles of finely divided matter, meteoric dust, for example, obstruct and modify to some extent the light transmitted from a distant star to an observer on the Earth. Whether the effect is appreciable depends upon the amount of material distributed along the path traversed by the light; with anything like uniformity of distribution the amount will increase with the distance. The result is a slight change of color; other things being equal, a distant star will be redder than one less remote, just as the Sun is redder at sunset than at noon because of the greater distance traversed by its rays in passing thru the dust-laden atmosphere of the Earth. The question is so important that much attention has been given to it, altho final results have not yet been obtained. But the circumstances are significant and show again the intimate relationship of different classes of phenomena.

It is characteristic of the effect in question that the change in color modifies only the continuous spectrum, whose intensity in the violet is reduced relatively to that in the red; the spectrum lines, which in the main determine the spectral type, remain unchanged. Comparing now the colors of near and distant stars of the same spectral type, we find that the distant stars are actually redder than our nearer neighbors. The observational result is clear enough, but its interpretation requires caution, for at this point we recall a result of observations on the Sun, namely, the

great difference between the spectra of the center and the edge of the solar disk. This appears in many of the lines, tho it escapes attention when the dispersion is low; but most striking is the greater redness of the light from the limb, due to the greater effective thickness of the atmosphere at this point. It is possible therefore that the color differences in stars of the same spectral type may be due to differences in the thickness of their atmospheres, which presumably will exist if the stars differ in size.

Now the two groups of stars whose colors were examined certainly differ in size, for it happens that the distant group has about the same average apparent brightness as the nearer; its actual brightness, and hence the radiating surfaces of the stars, must in consequence be much greater than in the case of the nearer group. The difference in intrinsic luminosity cannot be due to a difference in brightness per unit area of surface, for that would imply a difference in temperature and, therefore a difference in spectral type, whereas the types of the objects compared are the same. The observed differences of color may thus have nothing to do with the loss of light in space, but depend instead upon the size, or, as more commonly stated, upon the intrinsic luminosities or absolute magnitudes of the stars. A rediscussion of the material from this standpoint leaves little doubt that absolute magnitude is capable of accounting for the greater part, if not all, of the change of color. This, however, does not settle the question of space absorption, for the objects examined, even those of small proper motion, are only moderately remote as stellar distances go, and the phenomenon may still be of importance for very distant objects. The subject will be considered again in another connection.

It is of interest to follow the relation between absolute magnitude and spectrum a little farther. We have seen that the distribution of intensity in the continuous spectrum varies with absolute magnitude. A study of the spectra of the center and edge of the Sun's disk also suggested the possibility of a relationship between intrinsic luminosity and the characteristics of certain lines; and a special investigation has shown that the relative intensities of various pairs of lines are a reliable criterion of absolute magnitude, and in any given case may be used for its calculation.

This result is of the greatest importance; the possibility of determining the intrinsic brightness of a star implies the possi-

bility of finding its distance, for distance is easily calculated when both real and apparent brightness have been determined. Thus if the candle power of a street lamp be known, and its apparent brightness be observed, the calculation of its distance is a matter of the most elementary sort. Altho at present applicable only to the intermediate and later types of spectra, this method of measuring the distances of stars will undoubtedly prove a most effective instrument for further study.

These two or three illustrations are typical of the significance of the more extended programs of spectrographic observations now in progress at Mount Wilson. The bearing of certain individual results may also be mentioned briefly.

There can be little doubt that different spectral types represent different stages of stellar development, but until recently no single star has been seen actually to change its type. Presumably such variations are dependent upon changes of surface temperature, and in most cases are probably to be classed with the slowly varying phenomena of an evolutionary type.

For some years it has been known that many of the short-period variable stars undergo marked changes in color, synchronously with their variations in light. A variation in color implies a change in spectrum; to determine the nature of this change, one of the brighter cluster-type variables, RS *Boötis* with a period of only nine hours, was observed with a spectrograph throughout its cycle of light fluctuations. The photographs showed an unmistakable change in the type of spectrum, ranging from Fo at the minimum to B9 at maximum. The rapidity of the change —the interval from minimum to maximum is less than two hours— is extraordinary, and suggests that, whatever the conditions within the star, those which determine the main characteristics of its spectrum are very superficial.

Not out of harmony with this is another result, also derived from a variable star, the Algol RR *Draconis*. Here with the aid of photographic plates sensitive to different colors we find that the companion star, which in all probability has a low density, is relatively red, while the central, denser body is white. There is not much doubt that here, as usual, color is indicative of spectral type; if so, the usually accepted relation between density and spectrum is reversed. The result adds to the gradually accumulating evidence that spectrum represents a surface condition,

and that among the redder spectral types are to be found low as well as high density stars, while the whiter objects occupy an intermediate position. The bearing of these results upon the order of stellar development is apparent, altho the data are not yet sufficient for final conclusions.

Spectroscopic observations of stars fainter than the tenth or eleventh magnitude can be made only with a great sacrifice in precision and detail, and then only with the aid of very long exposures. The study of the fainter stars therefore follows other lines, one of the most important being the measurement of brightness. A statistical discussion of the magnitudes of large numbers of stars throws much light upon the structure of the universe, and, in the absence of numerous determinations of distance, is indispensable for the investigation of stellar distribution.

The work of the Observatory in this field has involved, first, a critical examination of the methods of photographic photometry and the determination of fundamental standards of brightness (the North Polar Standards), both photographic and photovisual, for a graded series of objects from the brightest down to the faintest easily observable with the 60-inch reflector; and, second, the establishment of secondary standards in the Selected Areas on, and north of, the equator. The latter part of the program carries with it the determination of the brightness of all the stars in these regions down to about the 18th magnitude. The magnitudes, on a homogeneous system, of perhaps a hundred thousand stars will thus be available for a discussion of the all-important relations connecting magnitude, numbers of stars, and galactic latitude.

It is planned also to determine the photovisual magnitudes (visual magnitudes derived by a photographic method) for a considerable number of these objects, in order that their colors may be learned. Since photographic and photovisual magnitudes are measures of the intensity of different regions of the spectrum, their difference, the color-index as it is called, may be taken as a measure of a star's color. A knowledge of this quantity gives a clew to physical condition, much less satisfactory than that afforded by the spectrum, but nevertheless a precious bit of information when the object is too faint for spectroscopic observation.

The value of a knowledge of star colors is illustrated by a suggestive result shown by the colors of the North Polar Standards. As one approaches the faint objects, the whiter stars gradually

disappear. At the 18th magnitude of the photovisual scale there seem to be few or none whiter than the Sun, which stands about midway in the color scale. On the other hand, white stars are known to be present among the faint objects in the Milky Way.

The extent to which this phenomenon depends upon position with respect to the Milky Way, remains yet to be determined.

This excess of redness in the fainter objects raises again the question of light scattering in space. Since on the average the very faint stars are at enormous distances, their colors may have been modified to an appreciable amount in the manner previously indicated, altho the large and small proper motion stars failed to give any certain evidence of scattering. Whatever the cause, it acts in opposition to the influence originating in absolute magnitude, for we know that the fainter stars are of smaller average luminosity than the brighter objects, and ought, therefore, so far as this factor alone is concerned, to be relatively white. Actually, as just stated, they are much redder than the nearer objects. Space absorption apparently would account for the phenomenon, but it may also be due to the fact that the faint stars are intrinsically red,—that they are of late spectral type. A final decision must await the accumulation of further data. In one direction —that of the cluster in *Hercules*—it is reasonably certain, however, that there is no considerable amount of absorption. This object is certainly at a very great distance, perhaps beyond the boundaries of the galactic system. Anything like a uniform distribution of material capable of producing light scattering would make all the stars in the cluster intensely red, unless the absorption coefficient is much smaller than the values usually assigned. As a matter of fact, the colors seem to be perfectly normal, and show, moreover, a normal relation to the spectra, which, with much difficulty, have been determined for a few of the stars.

In this brief survey of certain phases of the work of the Solar Observatory, there has been no account of many important investigations: for example, a correlation of solar, stellar, and laboratory observations of spectra which has given information as to the temperature and pressure in stellar atmospheres; the connection of the Wolf-Rayet stars with a later stage in the development of new stars; the direct determination of parallaxes; the photography and study of nebulae; the systematic investigation of the characteristics of star clusters; and the miscellaneous obser-

vations, both photometric and spectroscopic, of many variable stars. All these stand in an intimate relation to the problems outlined in a general way in the earlier paragraphs of this account.

In closing, one other feature of the Observatory's organization, perhaps more accurately, of its administration, should be mentioned. Besides the services rendered by the regular members of the staff, it has had the stimulating support of a considerable number of men of distinction, who, at one time or another, have joined in its activities, sometimes only briefly as visitors, and sometimes for longer intervals in the closer relation of research associates. First among these associates stands Kapteyn, who for several years has regularly spent the summer on Mount Wilson. Something of the Observatory's indebtedness to his wise and helpful counsel will have been evident from the preceding pages. But there are others, among them Nichols and Julius, Gale and Störmer, and Koch, Chamberlin, and Wood. With problems as wide in scope as those under investigation at Mount Wilson, questions of the most varied import are constantly arising. These frequently lead into fields of activity in which others are more qualified to speak than ourselves. Temporary associations of such individuals with its staff have given the Observatory the advantages, both of expert assistance and advice, and of the great stimulation which comes from contact with fresh and original points of view.

PLANETARY PHENOMENA FOR SEPTEMBER AND OCTOBER, 1917

By Malcolm McNeill.

Phases of the Moon, Pacific Time.

Full Moon....	Sept. 1,	$4^h\ 28^m$ A. M.	Last Quarter..	Oct. 7,	$2^h\ 14^m$ P. M.
Last Quarter..	" 7,	$11^h\ 5^m$ P. M.	New Moon...	" 15,	$6^h\ 41^m$ P. M.
New Moon....	" 16,	$2^h\ 27^m$ A. M.	First Quarter..	" 23,	$6^h\ 38^m$ A. M.
First Quarter..	" 23,	$9^h\ 41^m$ P. M.	Full Moon....	" 29,	$10^h\ 19^m$ P. M.
Full Moon....	" 30,	$12^h\ 31^m$ P. M.			

The Sun reaches the Autumnal Equinox and Autumn begins September 23, 7 A. M., Pacific Time.

Mercury is an evening star at the beginning of September but is too near the Sun for naked eye observation, setting considerably less than an hour after sunset. The distance between the bodies diminishes rapidly and inferior conjunction is reached on September 18. *Mercury* then becomes a morning star and continues